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(56) Documents Cited

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## (54) Radio frequency antenna

(57) A quadrifilar radio frequency antenna intended primarily for the reception of circularly polarised transmissions has the helical antenna elements (10A - 10D) deposited upon a dielectric material of high dielectric constant and of cylindrical form (13). Within the cylinder is contained the means whereby the signals received by the said elements are transformed to a form more suitable for further processing eg. a split tube balun (see Fig. 2 not shown). This is achieved by depositing conductors upon a dielectric material of high dielectric constant and of cylindrical form (22), co-axial with (13). Around the cylinder (13) if a further cylinder (19) which provides a means of varying the operating frequency. The interconnection of the parts into a rigid single assembly is to be achieved by a single soldering operation. The results in a smaller than could be achieved using prior art. The antenna is especially useful for GPS reception.

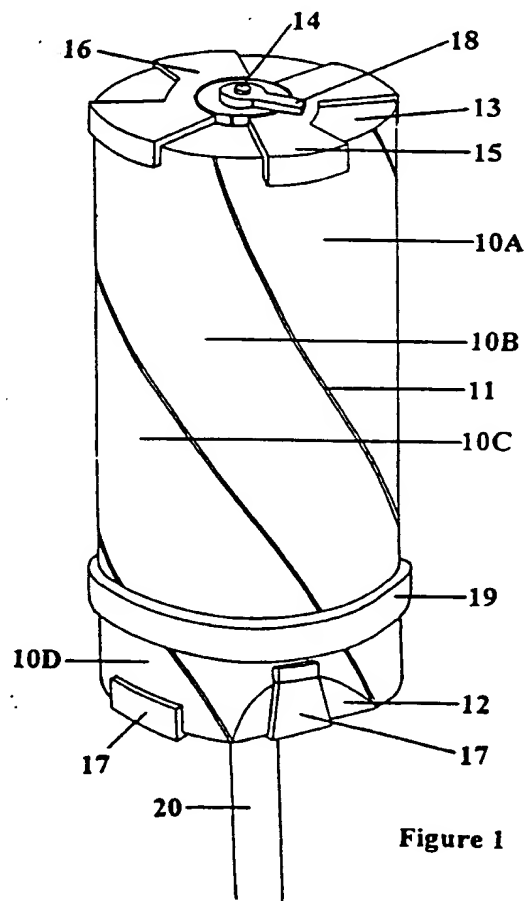


Figure 1

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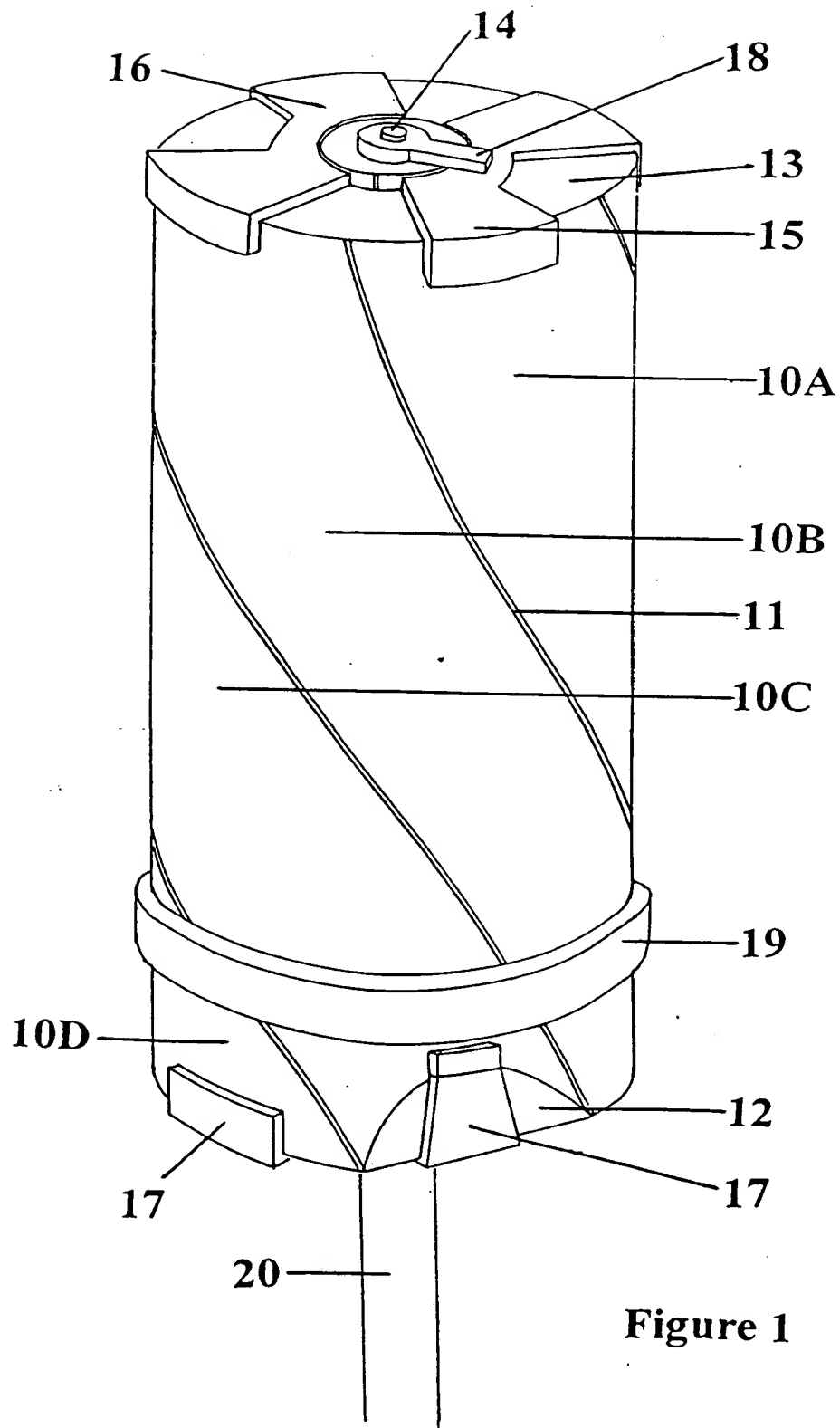
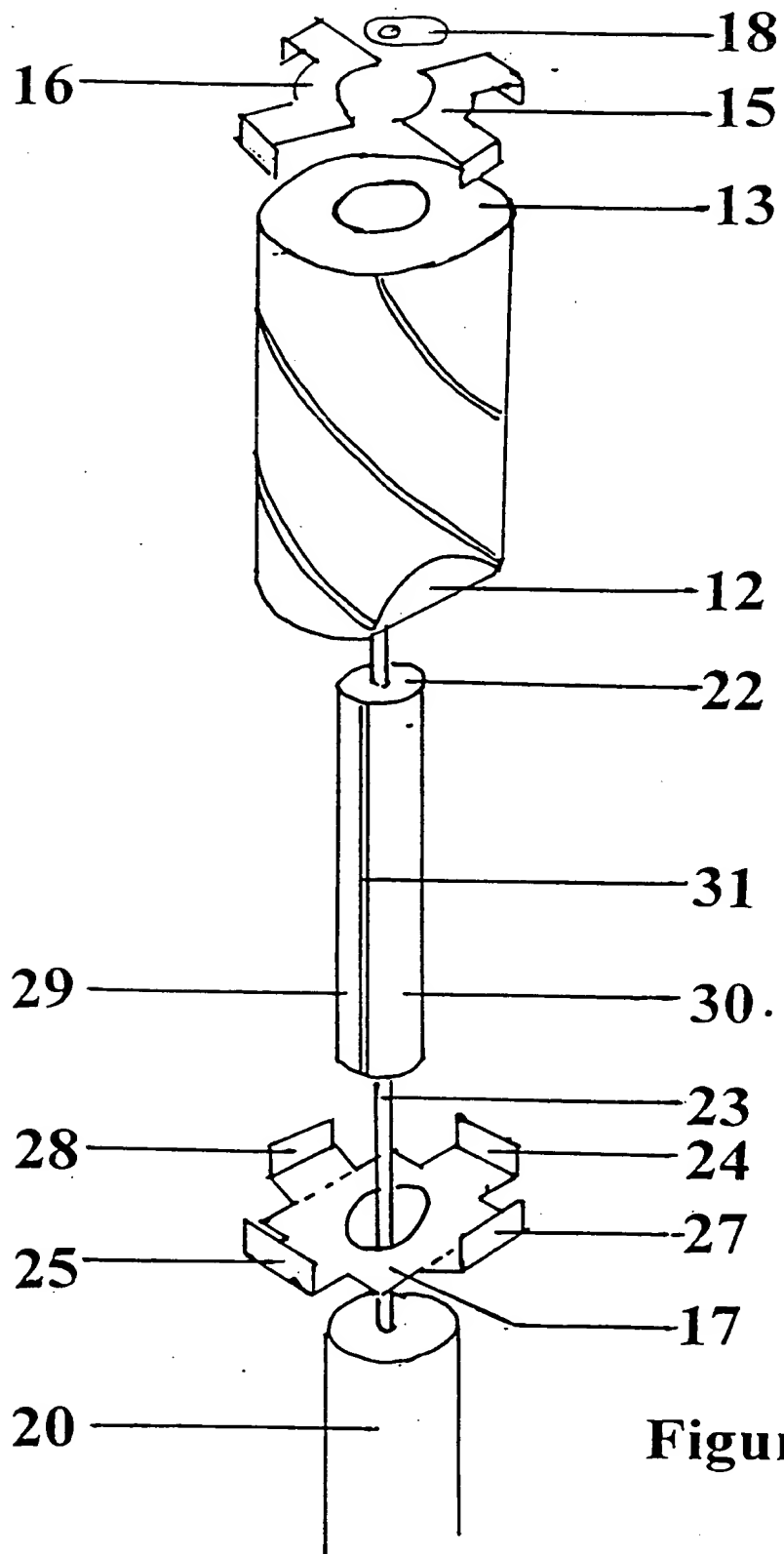


Figure 1



The quadrifilar antenna is well known, having been disclosed by C.C. Kilgus in IEEE Transactions on Antennas and Propagation, July 1968, pages 499 and 500. In this paper the antenna is shown to be sensitive to circularly polarised transmissions. If the antenna is oriented with its major axis vertical then the horizontal polar diagram is circular, whilst the vertical polar diagram is of cardioid shape, having substantially equal sensitivity at angles of elevation from -10 to 90 degrees. Thus the antenna is ideally suited to the reception of signals from satellites. The paper also discusses the application of a split tube balun as a solution to the problem of transforming from the balanced signals developed by the antenna to the unbalanced signals found on the transmission line that is conventionally used to convey the signals from the antenna to the receiving apparatus. A variation of the split tube balun in which the centre conductor diameter is varied to achieve impedance matching is also described. Whilst the half turn helix is often the preferred embodiment, the principle may be applied to other fractional turn helices. In summary, the quadrifilar helix antenna will comprise two bifilar helices driven in phase quadrature to satisfy the requirements for circular polarisation, and combined in parallel to provide the received signal. This latter feature results in a low source impedance necessitating the inclusion of matching to the feeder of normal characteristic impedance, 50 ohms. Given operation at the GPS frequency of 1575.42 MHz, the dimensions of a typical prior art antenna will be about 20 mm diameter and about 50 mm long. If environmental protection is required then the inclusion of a radome will increase these dimensions.

According to the present invention there is provided a resonant antenna of small size that embodies the general principles of the quadrifilar helix antenna. These principles include a means by which the phase quadrature of the two bifilar helices may be adjusted, and means whereby the transformation from a low impedance, balanced structure, namely the antenna elements, to an unbalanced defined impedance, namely the feeder, may be achieved. The method of implementation, whereby these principles are obtained in the present invention, differ from those used in prior art embodiments of the principles of the quadrifilar helix antenna. In addition, a means may be included whereby the resonant frequency may be varied over a small range to compensate for the inevitable manufacturing tolerances.

It is an object of the present invention to provide an antenna of small size that is suitable for mass production methods, but which retains the radiation properties of the quadrifilar helix antenna of prior art. The preferred embodiment includes a low cost, low skill method of adjusting the resonance of the antenna.

Prior art antennas use antenna elements that are immersed in an environment approximating to that of free space. Even when the elements are supported by a material medium, the medium is of minimal thickness required to produce the required mechanical properties, and is of low

dielectric constant. Thus the element lengths which may be one half wavelength long at the operating frequency have a physical length approximately one half wavelength long at the operating frequency in free space. In the present invention, the interior of the antenna comprises a material of high relative dielectric constant. Such materials, having a relative dielectric constant of 46 are readily available, but the use of more easily obtained material with a relative dielectric constant of say, 25 will result in an antenna of substantially smaller size than prior art antennas. To a first approximation, the size reduction is proportional to the square root of the relative dielectric constant. Thus the use of the suggested material will lead to an antenna approximately 1/5 of the size of the prior art antenna. The preferred method of design of the antenna of the lowest cost, starts with the identification of a suitable dielectric material that can be obtained in cylindrical form with an axial hole of chosen dimensions and to accept the resulting size reduction. The dielectric material will usually be at the higher end of the range of dielectrics produced by the manufacturer. Generally, a material of lower dielectric constant will be required for the split tube balun. The pattern of antenna elements (10A - 10D) on the outer surface may be produced by adopting one of the several methods that are now well known. For example, the outer cylindrical surface may have deposited upon it a highly conductive metal, then the 4 helical conductors may be formed by selectively removing the metal along 4 helical paths, or the cylinder may be selectively plated with a conducting metal of the required helical pattern. There is an increase in operating bandwidth, and an increase in mechanical robustness by maximising the width of the helical elements (10A - 10D). The intra-element separation (11) may be as small as manufacturing tolerances allow. The helical pattern is typically one half turn, but the method allows for any degree of rotation. The correct phase quadrature operation is obtained by choosing resonant frequencies for the two bifilar helices (10A - 10C) and (10B - 10D) to be equally disposed about the required frequency of operation. In one embodiment within the scope of the invention, the lower of the two resonant frequencies is determined by the size of the outer cylinder (13). The higher resonance is then produced by grinding away dielectric material to produce two diametrically opposed surfaces, equally inclined to the major axis of the antenna. The radial position will be chosen to intercept one only of the bifilar pairs. In another embodiment it is the upper resonance that is determined by the size of the outer cylinder (13), and the lower resonance is then obtained by adding suitable impedance elements which can be incorporated into the conductor structure (17) at the proximal end of the antenna, such that the electrical length of the bifilar helix (10A - 10C) is shorter than that of the bifilar helix (10B - 10D). In another embodiment, the width of the bifilar helix elements (10A - 10C) is chosen differently to the width of the elements (10B - 10D). By using one of these methods or more than one in combination, the two resonances may be achieved.

Given the correct phase quadrature operation, the signals produced will be balanced about earth potential, and of low source impedance. A split tube balun incorporating a quarter wave transformer is the classical way of transforming from the given signal source to unbalanced

signals at the usual characteristic impedance of 50 ohms. However, the prior art solution is not suitable for embodiment within this invention, since the length of the transforming section so produced would be much longer than the antenna which is the subject of this invention.

In this invention the length of the transforming section is approximately the length of the outer cylinder (13), and the diameter of the central conductor is most conveniently chosen as the diameter of the central conductor of the semi rigid coaxial cable (20) that will be used as the feeder. The outer diameter of the dielectric material to be used in the transforming section, and the relative dielectric constant of said material, provide the two degrees of freedom required to simultaneously satisfy the impedance requirements and the line length.

One embodiment within the scope of this invention is to produce a hollow cylinder of dielectric material with the calculated properties, and to form, axially, on its outer surface two conductors, insulated from one another, each occupying almost one half of the cylindrical surface area. The inner diameter will then be approximately the diameter of the centre conductor of the feeder.

In another embodiment, the outer cylinder (13) will carry the two conductors deposited on a central axial hole of the required diameter, and the central conductor of the feeder will be passed through a hollow cylinder of the calculated length and dielectric constant. In another embodiment, which would find application where a material of higher dielectric constant could be obtained more conveniently, or cheaply, would be to choose a shorter length of this higher dielectric constant material, and to leave a short air gap so that the resulting electrical length at the operating frequency was still correct. In this embodiment it will be necessary to deposit the two conductors on the inner diameter of the outer cylinder (13).

The method of connecting the assembly together in a single soldering process will be determined by the choice of the alternatives described above.

A specific embodiment of the invention will now be described.

Figure 1 shows in perspective the antenna and part of the feeder used to connect the antenna to the rest of the apparatus (not included);

Figure 2 shows in perspective an exploded view of the component parts of the antenna.

In this preferred embodiment, the helical antenna elements (10A - 10D) are deposited upon the surface of a right hollow cylinder (13), and occupy approximately one half turn of revolution. The cylinder is of high dielectric constant, and will form a substantial part of the antenna structure. Correct phase quadrature operation will be secured by arranging the two resonances of the bifilar loop to be equally disposed about the operating frequency. In this preferred embodiment the lower of the two resonances is to be determined by the size of the outer cylinder

(13). The higher resonance is then produced by grinding away dielectric material to produce two diametrically opposed surfaces, equally inclined to the major axis of the antenna. The radial position will be chosen to intercept one only of the bifilar pairs, here shown as (10A - 10C). (12) shows one of the two ground surfaces, the other being hidden from view.

The diameter of the central axial hole in this first cylinder is governed by considerations of the split tube balun member (22). It is convenient to consider the design of this component now. The helical elements provide an electrical signal that is balanced, and of low source impedance, typically less than 20 ohms. The normal feeder is unbalanced and typically 50 ohms characteristic impedance. A split tube balun incorporating a quarter wave transformer provides a suitable matching mechanism. It is not convenient to adopt normal design methods in this case. In this application the inner conductor (14 and 23) diameter need not be changed, since the outer diameter and the dielectric constant of the cylinder (22) provide the two degrees of freedom required to simultaneously satisfy the impedance requirements and the line length. In this preferred embodiment it is convenient to make the quarter wavelength required for the quarter wave transforming action equal to the length of the outer cylinder (13). Solving the two equations simultaneously provides the dielectric constant and the outer diameter of the inner cylinder (22).

The central axial hole of the cylinder (22) should be chosen such that after taking engineering tolerances into account, the conductor (14 and 23) is a good quality sliding fit.

The conductor pattern on the cylinder (22) consists of two longitudinal conductors (29, 30) each occupying approximately one-half of the circumference of the cylinder over the length of the cylinder. Note that the intra-conductor spacing (31) may be made as small as engineering tolerances allow. Only one space (31) is shown, the second is hidden.

It should be noted that the actual practical length of the cylinder (22) should exceed the length of the outer cylinder (13) by a length equal to the thickness of the metal used to manufacture the two quadrants (15) and (16) plus the thickness of the conductor at the proximal end (17). This enables essential electrical connections to be made at final assembly.

The outside diameter of the cylinder (22) determines the inner diameter of the central axial hole in the outer cylinder (13). Taking engineering tolerances into account, the cylinder (22) should be a good quality sliding fit in the outer cylinder (13).

The lower conductor (17) is a simple pressed component that plays an important part in the final construction phase. The central hole size is governed by the diameter of the cylinder (22). The tabs (24) and (25) make contact with one of the bifilar elements, here (10B) and (10D), whilst the tabs (26) and (27) are angled towards the axis of the antenna at the same angle as the ground areas (12). The extreme parts of (26) and (27) make contact with the other bifilar element, here (10A) and (10C).

The semi rigid cable (20) usually used as the feeder must have its outer conductor finished to make a good butt joint with the conductor (17) to ensure a good soldered connection.

Figure 1 shows quite clearly the method of connection at the distal end. Note particularly the

orientation of the cylinder (22) such that the gap (31) and the second gap, (not shown) separate the two quadrants (15) and (16). The tab (18) is used to connect the central conductor (14 and 23) to one of the quadrants (15) or (16).

Final assembly is straightforward in that the parts are self aligning. Given that the mating surfaces are coated with a solder paste, then a single pass in an infra red reflow soldering process will make secure all of the necessary interconnections and produce a single rigid entity. It is now necessary to take into account the effect of normal engineering tolerances on the performance of the antenna. A method of adjusting the resonance frequency after assembly is required. Even with the broad helical elements, the resonance frequency may well fall outside the limits of acceptance. There is a method whereby the resonance frequency may be reduced by encircling the outer cylinder (13) with a short cylinder of dielectric material (19). As this material is moved axially towards the centre of the antenna, the frequency will fall. The magnitude of the change is a few percent only, and is dependant upon system constants in an indeterminate manner. To make use of this property the natural resonant frequency must be above the required resonant frequency. It is convenient to use a dielectric material with elastic properties so that the tuning position will be retained after adjustment.



## Claims

1. A radio frequency antenna comprising a plurality of helical elements arranged round a common axis and deposited on a material of high relative dielectric constant of cylindrical form, a substantially axially located feeder structure, and a conductor pattern connecting the helical elements to the feeder structure.
2. An antenna according to claim 1 wherein the conducting elements at the distal end of the antenna comprise two identical conductors, whilst at the proximal end a single conductor connects all of the antenna elements to the outer conductor of the feeder structure in a manner that ensures the correct phase quadrature operation.
3. An antenna according to claims 1 and 2 wherein each helical element executes a fractional turn around the supporting high relative dielectric constant material, said material to form a substantial portion of the antenna assembly.
4. An antenna according to claims 1,2 and 3 wherein a split tube balun has a length approximately that of the antenna assembly, and an outer diameter governed by the relative dielectric constant of the material of the split tube balun and the characteristic impedance of the split tube balun required for matching the balanced, low impedance of the antenna elements to the unbalanced coaxial antenna feeder.
5. An antenna according to claim 4 in which the split tube balun is produced from a hollow cylinder of high relative dielectric constant material having on its surface two conductors extending the length of the cylinder and each occupying almost one half of the cylinder surface area, such that the conductors are insulated from one another.
6. An antenna according to claim 4 in which the electrical properties of the split tube balun are completed at the time of soldering the whole antenna assembly together.
7. An antenna according to any preceding claim in which the two resonances required for correct phase quadrature operation are produced by the removal of dielectric at the proximal end of the antenna to produce two diametrically opposed surfaces equally inclined to the axis of the antenna, and which are positioned radially to intercept one only of the bifilar pairs.
8. An antenna according to any previous claim that carries on its outer surface a short cylinder of dielectric material having elastic properties such that tuning the antenna over a limited range

may be achieved by the variation in the axial position of the cylinder of dielectric material, said cylinder remaining in position after the tuning action due to the elastic nature of the material.

9. An antenna according to any previous claim that is self aligning at the final assembly stage, and in which the piece parts, having been prepared with a suitable solder paste on mating surfaces, may be soldered together at one pass in an infra red reflow soldering process, all mating surfaces having been chosen so that surface tension and gravity alone will ensure correct placement of the piece parts.

10. An antenna according to any previous claim in which the antenna structure comprises two coaxial cylinders of differing high dielectric constant, usually ceramic, material, carrying on their surfaces a conductor pattern and in which the inclusion of air within the structure is minimised by the use of close fitting, sliding surfaces.

**Amendments to the claims have been filed as follows**

1. A radio frequency antenna comprising a plurality of helical elements arranged round a common axis and deposited on a material of high relative dielectric constant of cylindrical form, such cylinder to provide a substantial portion of the antenna. Within this cylinder is located a second coaxial cylindrical structure, also of high, but usually different, relative dielectric constant, constructed such that the presence of air within the total structure is minimal. In such an assembly the electrical properties of the antenna are determined largely by a consideration of the high relative dielectric constant, and by a consideration of the electric fields that exist within the high relative dielectric constant material. The antenna is completed for practical use by the addition of a substantially axially located feeder structure, and a conductor pattern connecting the helical elements to the feeder structure.
2. An antenna according to claim 1 wherein the conducting elements at the distal end of the antenna comprise two identical conductors, whilst at the proximal end a single conductor connects all of the antenna elements to the outer conductor of the feeder structure in a manner that ensures the correct phase quadrature operation.
3. An antenna comprising a cylindrical structure made from high relative dielectric constant material, carrying conductors deposited on the surfaces of said material, and constructed in such a way so that air within the structure is largely excluded, such that the physical size of the antenna is substantially dependant upon the high relative dielectric constant, thus being substantially smaller than an antenna that includes a substantial amount of air within the structure.
4. An antenna according to claims 1,2 and 3 wherein a split tube balun has a length approximately that of the antenna assembly, and an outer diameter governed by the relative dielectric constant of the material of the split tube balun and the characteristic impedance of the split tube balun required for matching the balanced, low impedance of the antenna elements to the unbalanced coaxial antenna feeder.
5. An antenna according to claim 4 in which the split tube balun is produced from a hollow cylinder of high relative dielectric constant material having on its surface two conductors extending the length of the cylinder and each occupying almost one half of the cylinder surface area, such that the conductors are insulated from one another.
6. An antenna according to claim 4 in which the electrical properties of the split tube balun are

completed at the time of soldering the whole antenna assembly together.

7. An antenna according to any preceding claim in which the two resonances required for correct phase quadrature operation are produced by the removal of dielectric at the proximal end of the antenna to produce two diametrically opposed surfaces equally inclined to the axis of the antenna, and which are positioned radially to intercept one only of the bifilar pairs.
8. An antenna according to any previous claim that carries on its outer surface a short cylinder of dielectric material having elastic properties such that tuning the antenna over a limited range may be achieved by the variation in the axial position of the cylinder of dielectric material, said cylinder remaining in position after the tuning action due to the elastic nature of the material.
9. An antenna according to any previous claim that is self aligning at the final assembly stage, and in which the piece parts, having been prepared with a suitable solder paste on mating surfaces, may be soldered together at one pass in an infra red reflow soldering process, all mating surfaces having been chosen so that surface tension and gravity alone will ensure correct placement of the piece parts.
10. An antenna according to any previous claim in which the antenna structure comprises two coaxial cylinders of usually differing, high dielectric constant, usually ceramic, material, carrying on their surfaces a conductor pattern and in which the inclusion of air within the structure is minimised by the use of close fitting, sliding surfaces.



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**Claims searched:** 1-10

**Examiner:** John Betts  
**Date of search:** 31 October 1995

**Patents Act 1977**  
**Search Report under Section 17**

**Databases searched:**

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:  
UK CI (Ed.N): H1Q (QDJ)  
Int CI (Ed.6): H01Q 11/08  
Other: On-line: WPI, CLAIMS, INSPEC

**Documents considered to be relevant:**

Category	Identity of document and relevant passage	Relevant to claims
X	GB 0840850 (Telefunken) see figures 3a, 3b variation	1
X	EP 0521511 (Sharp) see figure 1	1-3
Y	US 5349365 (Ow and Connolly) whole doc.	1-3
Y	US 5329287 (CAL) see col. 1 lines 10-30 & claim 1	1-3
Y	US 5255005 (L'Etat Francais) whole doc.	1-3
Y	WPI ABSTRACT Accession No. 95-249973/33 & JP7154137 A see abstract	1-3

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.